THE ANALYSIS OF PHONOGRAPH RECORDS.[1]

AFTER describing the general characters of waves, as regards pitch, amplitude, and form, Dr. McKendrick said :—

Thus we can now understand what is meant by a compound wave, and you will appreciate the statement that compound waves may be very complex in character. If you look at the curves showing the resultant waves, you will see that they represent, in a way, the character of the variations of pressure made on the drum-head. With simple pendular waves, the drum-head moves out and in with perfect regularity, like the movements of a pendulum. The physiological effect of such simple pendular vibrations is a sensation of a pure tone, such as you hear when I bow this tuning-fork. But if a compound wave falls on the drum-head, it is not so easy to follow with the imagination the variations of pressure. While these variations occur in regularly recurring intervals of time so as to give the sensation of the pitch of the fundamental tone, the movement may not be uniform on each side of the median line, indicating the position of repose of the drum-head, like the swing of a pendulum. Thus the drum-head may move in, owing to the increase of pressure, faster than it moves out, or the reverse; or it may move in a little distance, then return again to the starting-point and again move in, and it may return to the position of rest after one or more to-and-fro movements Again, it may be pushed in to the maximum distance, and remain in that position for a short time, and then return to the original place of repose. Thus the characters of the variations of pressure may vary to a remarkable degree—to a degree, with a very complex sound, that is to us almost inconceivable ; but we may be sure that these variations of pressure will be faithfully followed by the drum-head, and communicated by it to the deeper ear. When a compound wave thus falls on the ear, the result is a sensation of sound of a certain quality, or timbre, or clang, and we say that we hear the sound of various musical instruments, as in a brass band or an orchestra, or the sound of a particular instrument, a trombone, a flute, a harp, a clarionet, or the sound of a well-known voice that we can distinguish from all others.

He then described the attempts to record graphically the vibrations of bodies emitting sound from the time of Thomas Young down to 1874-75, when the phonograph was invented. In 1878, Fleeming Jenkin and Ewing succeeded in obtaining tracings of the records of vowel sounds on the tinfoil phonograph, and the curves were submitted to harmonic analysis. Since that time, the marks on the tinfoil of the first phonograph have been scrutinised by Grutzner, Mayer, Graham Bell, Preece, and Lahr. The imperfections of the tinfoil phonograph made progress impossible for ten years (from 1878 to 1888), during which time, however, Edison, Graham Bell, and others were engaged in working out the mechanical details of the wax-cylinder phonograph. The subject was then taken up by Hermann, and he succeeded in obtaining photographs of the vibrations of the vowel sounds, a beam of light reflected from a small mirror attached to the vibrating disc of the phonograph being allowed to fall on a sensitive plate while the phonograph was slowly travelling. The curves thus obtained were very beautiful. In 1891, Boeke, in a laborious microscopical research, measured the transverse diameters of the depressions on the wax cylinder at different depths, and from these measurements calculated the depths of the curves. He then reconstructed the curves on a large scale, and he also has been busily engaged in the analysis of vowel curves.

Recently also Pipping has traced and analysed the curves obtained by a kind of phonautograph constructed on the type of the drum-head of the ear, and R. J. Lloyd has written two valuable papers on the interpretation of the tracings obtained by Pipping and by Hermann.

Dr. McKendrick exhibited one of the first phonographs made in this country. It was constructed by the late Prof. Fleeming Jenkin in 1876. It represents the instrument in its simplest form. You observe how the drum travels from side to side as in the phonautograph. The drum has a deep spiral groove, the thread of which corresponds to that of the spindle on which the drum rotates, and it is covered with thin, soft tinfoil. The membrane has fixed firmly to its centre a stout little marker having a chisel-shaped edge. When sound waves fall on the membrane it vibrates, and as the drum is rotated, the edge of the needle pushes in the tinfoil into the spiral groove, and it makes a series of indentations corresponding to the variations of pressures produced by the sound waves. When the sound is reproduced, we run the point of the needle over these indentations by turning the drum, and the varying pressures on the needle point caused by the indentations act on the membrane, and reproduce the sound. Thus this simple mechanism records the *number* of vibrations, corresponding to pitch, the relative *amplitude* of the vibrations, corresponding to intensity or loudness, and the *form* of the vibrations which has reference to the quality of the sound.

Since this remarkable invention first appeared, the phonograph has been improved so as to make it now a valuable scientific instrument. Many are too apt to think of it as an amusing toy, or as an apparatus that will serve the practical purpose of a shorthand writer. It is both amusing and practical, but it is much more. It is now a scientific instrument worthy of a place in physical and physiological laboratories beside other instruments of scientific research, and those employed for demonstration in teaching. It merits this position because it makes it possible to study some of the phenomena of sound in a manner otherwise unattainable.

Since 1877 the phonograph has been immensely improved, and we now have it in the form that you see before you. The machine used in this country is so geared that the wax cylinder, $6\frac{7}{8}$ inches in circumference, makes two revolutions in one second, while the spiral grooves described on the cylinder are 1/200 inch apart. A spiral line about 136 yards in length may be described on the cylinder, and the recording or reproducing point travels over this distance in about six minutes.

I have also used the American model, now also before you, which resembles in all essential particulars the one I have just described, except that the grooves are 1/100 inch apart, instead of 1/200 inch.

The mechanism by which the glass disc or diaphragm communicates its movement is shown by means of the large model now before you. When sound waves fall on the glass disc, the latter is subjected to variations of pressure, as I have already explained. From the centre of the glass disc there comes a rod which passes to the end of a lever, and to this lever a counterpoise is attached. The end of the lever carries a sapphire point which, like a gouge, cuts a spiral groove on the surface of the wax cylinder. When there is increased pressure on the disc, the inclination of the edge of the gouge is directed downwards at such an angle with the surface of the wax cylinder as to cut a groove of a certain depth ; but when the pressure becomes less, the angle is changed, the gouge cuts more in a horizontal direction, and the groove ploughed out is not so deep. Consequently as with each vibration of sound we have, as I have already explained, increased pressure and diminished pressure, a series of marks of an oblong form are made in the bottom of the groove, each little mark corresponding to a vibration. The number of such marks, therefore, in a given distance—which, when the velocity of the movement is taken into account, represents a certain interval of time, say the one-fiftieth of a second—corresponds to the pitch of the note ; the depth of the marks corresponds to the intensity of the vibration ; and the form of the marks to the form of the vibration. Again, suppose a note is sung *diminuendo* to *crescendo*, and again to *diminuendo*, the depth of the groove will vary according to the intensity, at first shallow, gradually becoming deeper till the maximum depth has been reached, and again becoming more and more shallow. These marks, therefore, on the wax cylinder are the representations of the mechanical effects of the vibrations in all respects—number (pitch), depth (intensity or loudness), form (quality). It will be evident, therefore, that if we run over these marks again with the reproducing point, the glass disc will again vibrate to the impulses received by the ups and downs on the cylinder as to reproduce faithfully, but with diminished intensity, the original sound. It is, therefore, an investigation of great interest to study these marks, to reproduce them on such a scale as to enable us to study their form, and to let us see the ups and downs as we would do, suppose we could make a longitudinal section along the bottom of the groove, and looked at the marks sideways.

Before we set ourselves to the study of these marks, let me bring under your notice certain other branches of the investigation. In the first place, we may, to a wonderful extent, increase the volume of tone or loudness of the phonograph by the use of resonators. No doubt the *quality* of the tones is best appreciated by carrying the vibrations directly to the vicinity of the drum-head of the ear, as is usually done, by fine tubes; but this method is not always agreeable, and the pleasurable effect is sadly marred by the friction noises. Still the fact that tones are heard best in this way, *as regards their quality*, proves to my mind that the marks on the wax cylinder are accurate representations of the varying intensities of the pressures caused by the sound waves. Resonators, such as the large one you now see, increase the volume of tone, and you will notice how accurately the tones are reproduced.

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[1] Abstract of the Science Lecture for 1896, delivered to the Philosophical Society of Glasgow on December 16, 1896, by John G. McKendrick, M.D., F.R.S., Professor of Physiology, University of Glasgow.

Now, let us see what we can make of the marks. I have endeavoured to study the marks on the wax cylinder in three different ways—by casts, by photographs, and by mechanical devices.

As regards the first method—taking casts, which was also attempted by Hermann and Boeke—the results were not satisfactory. The most efficient method followed by me was to paint in the cylinder, with a camel-hair brush, a layer of celloidin dissolved in ether. This soon hardened, and the film could then be peeled off. The thin film thus obtained was then inverted on the stage of a microscope, and the marks were seen in relief. A photograph of the marks thus obtained is now on the screen (Fig. 1).

The depressions are well seen, and their differences as regards length are obvious. The method has the disadvantage of flattening out the marks.

I took numerous photographs, with the aid of the microscope and camera, of portions of the surface of the cylinder on which were records of many instruments and of the voice. I now show you on the screen examples of such records (Fig. 2).

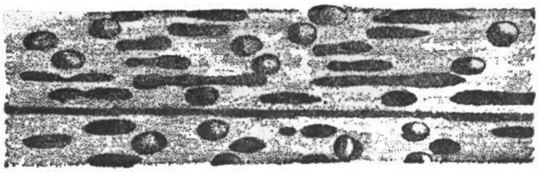

Fig. 1.—Celloidin cast (magnified) of marks on wax cylinder. Portion of record of a military band.

Each figure, from above downwards, represents the $\frac{1}{5}$th of an inch on the surface of the wax magnified fourteen diameters. The grooves seen in each figure are, on the wax cylinder, $\frac{1}{200}$th inch apart, and the length of the groove, from above downwards, represents in time the $\frac{1}{64}$th second—that is to say, when each tracing was recorded, the sapphire point of the recorder travelled over the distance represented in magnified proportions in the $\frac{1}{64}$th part of a second. By counting the number of indentations or marks, which in a photograph have a curious appearance of being in relief, one can at once determine approximately the pitch of the tone, the vibrations of which make the impression. The tones highest in pitch were obtained from the piccolo and the xylophone. Here the pitch was about 1920 vibrations per second. In Fig. *A* we have a picture of the vibrations produced by the tones of the violin, and it will be seen that they vary in character. Sometimes the marks are a little apart, and at other times they blend into each other, the mark widening out as the receding point cut into the wax and then contracting as it receded. It is to be borne in mind that even when the glass disc is not vibrating, the recorder ploughs a groove on the cylinder, and when the glass disc vibrates each vibration cuts deeper into the groove. The figure of the vibration of the tones of a flute (*B*) shows moniliform markings, indicating that the disc may not, in some instances, return to its position of rest for a short time. Sometimes the intensity of the tone is so great as to cause, after each deeply ploughed groove (as will be seen in the figure of the vibrations of the tones of an organ, *D*), a rebound lifting the recorder up to the surface of the cylinder, or even off the surface altogether. This is the explanation of the smooth spaces between the ends of the individual marks.

To obtain a mechanical representation of the curves is a very difficult matter. The difficulties were so far overcome by the device of Jenkin and Ewing with the tinfoil phonograph. The method followed by these observers, which was entirely mechanical, was to cause the disc of the phonograph to record its movements on a drum moved at the same rate as that of the cylinder. As I have already mentioned, Hermann photographed the oscillations of a beam of light reflected from a small mirror connected with the disc of the phonograph, the whole apparatus moving slowly. My method consists in the adaptation of a light lever to the phonograph itself, and so arranged that it (the point of the marker) would travel over all the ups and downs of the phonographic curve on the wax cylinder at an extremely slow rate. The obvious objection to any method of directly recording the ups and downs of the lever is that the inertia of the lever might cause extraneous vibrations, while, at the same time, the smaller marks on the wax cylinder might be missed. These objections, however, were removed by reducing the friction to minimum, and by moving the phonograph cylinder so slowly as to make the movement almost invisible to the naked eye. In this way inertia ceases to give trouble. The first arrangement gave curves of very small amplitude, a specimen of which I now show you.

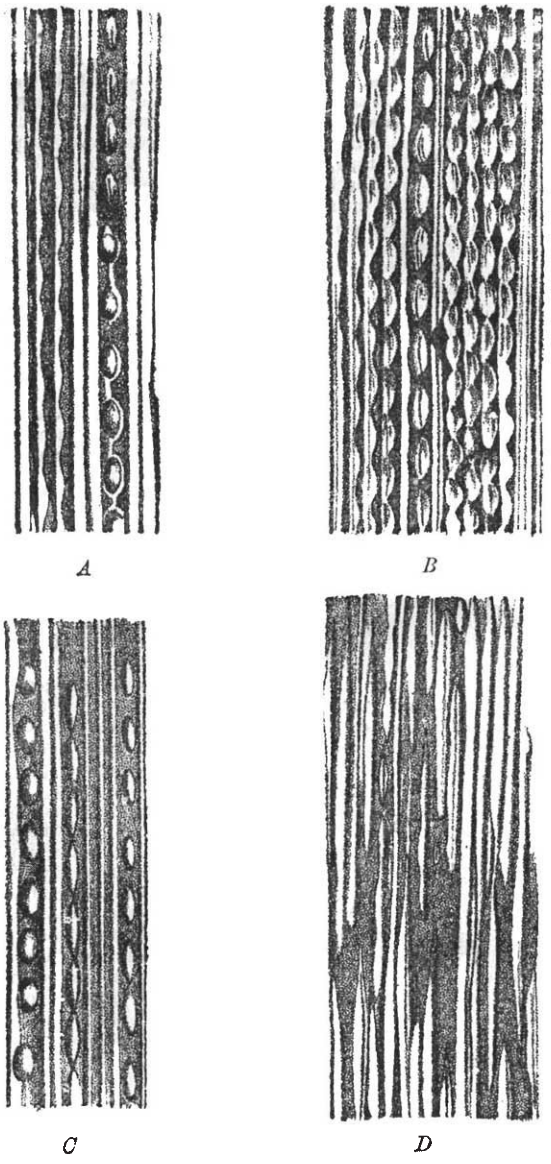

Fig. 2.—From photographs of portions of the surface of the wax cylinder. *A*, violin. *B*, flute. *C*, vowel *o*. *D*, full organ.

Various mechanical arrangements were employed, some of which I described to the Royal Society of Edinburgh in February last.

My attention has since been directed to perfecting a mechanism for obtaining a record of the vibrations.

The instrument now before you, which I shall call a *phonograph-recorder*, traces out, on a large scale, the curves of the indentations on the wax cylinder corresponding to each vibration of sound, and it does so in a way that seems to be highly satisfactory.[1]

Since the apparatus was brought to its present condition, I have been able to record the vibrations of the tones of several instruments, and also the tones of the human voice, both in singing and in speech. Illustrations of these I now show you (Fig. 3 .

First, with reference to speech, I wish to point out that when the record of a *word* is examined it is found to consist of a long series of waves, the number of which depends (1) on the pitch of the vowel constituents in the word, and (2) on the duration of the whole word or of its syllables individually. There is not for each word a definite wave form, but a vast series of waves, and, even although the greatest care be taken, it is impossible to obtain two records for the same word precisely the same in character. A word is built up of a succession of sounds, all usually of a musical character. Each of these sounds, if taken individually, is represented on the phonograph-record by a greater or less number of waves or vibrations, according to the pitch of the sound and its duration. The pitch, of course, will depend on the number of vibrations per second, or per hundredth of a second, according to the standard we take, but the number of the waves counted depends on the duration of the sound. As it is almost impossible to utter the same sound twice over in exactly the same fraction of a second, or in the same interval of time, the number of waves counted varies much in different records. The rate per unit of time determines the pitch, the number the duration of the sound. In a *word*, these successive sounds blend into each other, and, in many records, the passage from one pitch to another can be distinctly seen. The speech sounds of a man vary in pitch from 100 to 150 vibrations per second, and the song sounds of a man from 80 to 400 vibrations per second. The sounds that build up a word are chiefly those of the vowels. These give a series of waves representing a variation in pitch according to the character of the vowel sound. In the record of a spoken word the pitch is constantly moving up and down, so the waves are seen in the record to change in length. It is also very difficult to notice where one series of waves ends and where another begins. For example, in the word *Con-stan-ti-nople*, the predominant sounds are those of *o-a-i-o-ill*, and the variation in pitch is observable to the ear if, in *speaking* the word, we allow the sound of the syllables to be prolonged. If we look at the record of the word, we find these variations in pitch indicated by the rate of the waves, or, as the eye may catch this more easily, by the greater or less length of wave, according to the pitch of the sound. The consonantal sounds of the word are breaks, as it were, in the stream of air issuing from the oral cavity, and these breaks (I am not discussing the mechanism at present) produce sounds that have also often the character of vowel sounds. Thus, at the beginning of "Constantinople," we have, as will be observed on pronouncing the syllables very slowly, the sound *ŭkkō*. This sound is represented in the record by a series of waves. Then follow the waves of the vowel *o*. Next we have the sound *nn* (sound through the nose), also represented by a series of waves. Next the hissing sound *ss*, which has first something in it of the vowel *e* or *i*, and then the *iss-s*. This sound also is shown by a series of waves. Then there is *ta*, which has a double series of waves—(1) those for *it* or *t*, and the next for *a*. This passes into the prolonged vowel *a*, this into *in*, this followed by *ti* passing into the vowel *i*, then another *in*, then a long *o*, then a sound like *op*, and, lastly, the sound *ill*, a sort of double-vowel sound. As so many of these sounds have the character of vowels, it is impossible, by an inspection of the record, to say where one set of waves begins and another ends. There are no such breaks corresponding to the consonants; the vibrations of the consonants glide on as smoothly as those of the vowels. The *number* of waves producing a word is sometimes enormous. In "Constantinople" there may be 500, or 600, or 800 vibrations. A record of the words "Royal Society of Edinburgh," spoken with the slowness of ordinary speech, showed over 3000 vibrations, and I am not sure if they were all counted. This brief illustration gives one an insight into nature's method of producing speech sounds, and it shows clearly that we can never hope to reach such records in the sense of identifying the curve by an inspection of the vibrations. The details are too minute to be of service to us, and we must again fall back on the power the ear possesses of identifying the sounds, and on the use of conventional signs or symbols, such as letters of the alphabet, vowel symbols, consonant symbols, or the symbols of Chinese, which are monosyllabic roots often meaning very different things, according to the inflection of tone, the variations in pitch being used in that language to convey shades of meaning.

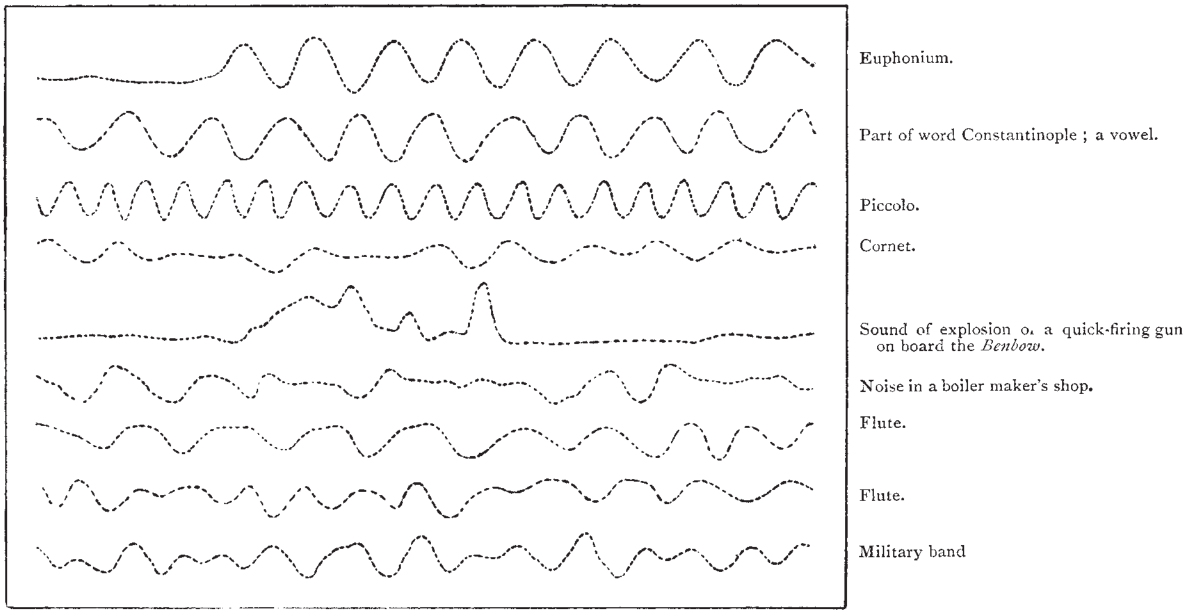

FIG. 3.—Specimens of curves obtained by phonograph recorder. Four inches = 1/120th sec. The curves read from left to right. The lower curve of the flute is continuous with the upper one, to show change of pitch. These curves are given to show the great variety of wave form. They are not sufficiently accurate for analysis. To obtain curves suitable for analysis, the greatest care must be taken.

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[1] For a diagram of the apparatus, see *Proc. Roy. Soc. Ed.*, December 7, 1896.

When human voice sounds are produced in singing, especially when an open vowel sound is sung on a note of definite pitch, the record is much more easily understood. Then we have the waves following each other with great regularity, and the pitch can easily be made out. Still, as has been well pointed out by Dr. R. J. Lloyd, of Liverpool, a gentleman who has devoted much time and learning to this subject, it is impossible by a visual inspection of the vowel curve to recognise its elements. Thus two curves, very similar, possibly identical to the eye, may give different sounds to the ear—that is to say, the ear, or ear and brain together, have analytical powers of the finest delicacy. No doubt, by the application of the Fourierian analysis, we may split up the periodic wave into a fundamental of the same period, and a series of waves of varying strength vibrating 2, 3, 4, 5, &c., times faster than the fundamental, and the relative amplitude of each of these may be determined. If all these waves of given amplitude and given phase acted simultaneously on a given particle, the particle would describe the vibration as seen in the original curve. Dr. Lloyd, however, is of opinion that even a Fourierian analysis may not exhaust the contents of a vowel, as it does not take account of inharmonic constituents which may possibly exist. Hermann and Pipping have also been investigating the analysis of vowel tones, and their investigations have revealed many difficulties. Hermann experimented with the ordinary phonograph, and obtained photographs of the movements of the vibrating glass plate. Pipping's curves were not obtained from the phonograph, but from the vibrations of a minute membrane made to represent the drum-head of the ear. His curves show large periodic waves with minute waves on their summits, and they suggest that the large waves may be vibrations due to the membrane itself. I therefore think that argument as to the character of vowels should be based only on records obtained from the phonograph itself, which is furnished with a vibrator that will not record its own periodic vibrations unless the sound be remarkably intense. In ordinary voice production and in ordinary singing, the vibrator of the phonograph faithfully records only the pressures falling upon it—no more and no less.

I shall now show you another method of recording, not the individual vibrations of the phonograph, but the variations in intensity of the sounds of the phonograph—the intensities of individual notes and chords. I was led to use this method by becoming acquainted with an instrument devised by Prof. Heurthle, of Breslau. He has succeeded in recording the vibrations of the sounds of the heart. I saw that his instrument was very useful, and I adapted it to the particular purpose in hand. Heurthle's instrument is an electro-magnet acting on a metal plate connected with the elastic membrane of a tambour. Another drum is connected with the first by an india-rubber tube. The metal plate of the first tambour is pulled down by the electro-magnet; thus the air is rarefied in the tube and in both tambours, and the lever of the second tambour moves. The next instant the lever flies back. We shall now connect Graham's variable resistance apparatus with the phonograph. As sound waves fall on it, a change is produced in the current passing through the electro-magnet; the latter acts on its tambour; a variable pressure is communicated to the other tambour; and if the lever of the latter is brought against a revolving drum, a tracing is obtained. I show you a little bit of such a tracing (Fig. 4).

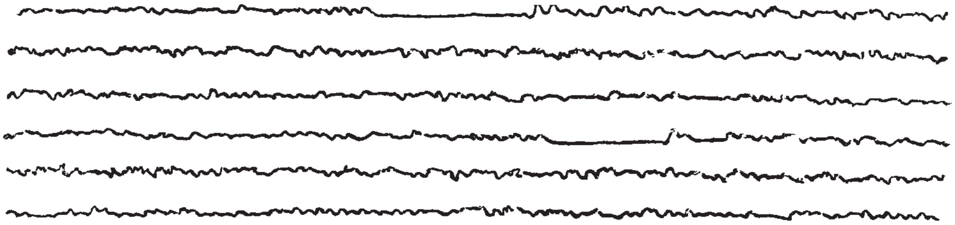

FIG. 4.—Portion of a record of the time and intensity of music played by a military band. Each curve represents a note or chord. The curves are read from right to left. The cylinder in which the record was taken was moving slowly, about 1 inch per second.

Each note and each chord is recorded, so that you get a mechanical tracing of the variations of intensity. Now this experiment suggested another of a different kind. Suppose I send the current not only through the variable resistance apparatus above the disc of the phonograph, but also through the primary coil of an induction machine. The wires from the secondary coil pass to two platinum plates dipped in weak salt solution. I now set the phonograph going; and when I put my fingers into the beakers containing salt solution, I *feel* the intensity of every note. The variation of intensity, the time, the rhythm, and even the expression of music, are all felt. I shall now place on the mandril of the phonograph a cylinder on which has been recorded another piece of music, with a faster *tempo*. I now feel a series of electrical thrills corresponding to every variation of intensity of sound coming from the phonograph. That method shows that the nerves of the skin can be stimulated by irritations coming to it at the rate of the notes and chords of rapid music. Some of the notes produced by the phonograph do not last longer than the five-hundredth or six-hundredth part of a second, but they are quite sufficient to stimulate the nerves of the skin, and, as I have pointed out, you can appreciate the variations of intensity. You can *feel* the long drawn-out notes from the saxhorn or trombone. You feel the *crescendo* and *diminuendo* of rhythmic movement, and you can estimate the duration of the note and chord. You feel even something of the expression of the music. It is rather a pity to say than even expression is mechanical. It is undoubtedly mechanical when you deal with the records of the phonograph. A number of interesting questions of a physiological nature are suggested by this experiment. The skin is not a structure that can analyse tone or distinguish pitch; it cannot tell you the number of vibrations, although there is a curious approach to it. While it is not by any means accurate, you can distinguish tones of low pitch—very low tones—by a feeling of "intermission." Experimenting in this way, you may stimulate by interrupting this circuit at the rate of 30 or 40 or 50 breaks per second, and yet the skin will tell you the individual breaks; but when you get above that number you lose the consciousness of the individual breaks, and you have a more or less continuous sensation. The phonograph does not necessarily give you 50 or 60 *stimuli* to produce a sensation of a tone; you do not require that number. I found that 8 or 10 per second may give you the sensation for a tone of any pitch. In the same way you may be able to notice a slight difference up to perhaps 50 or 60, but above that the sensation seems continuous. It is not the number of *stimuli* that determine pitch, but the rate at which the *stimuli* affect the sense organ, whether it be ear or skin. Then the question arises, What is it in the skin that is irritated? It is not the corpuscles. They have to do with pressure. There is no organ for the sense of temperature. You may say that the feeling is muscular. Possibly it may be so; but the effect is most marked when the current is so weak as to make it unlikely that it passes so deep as to reach the muscles.

This experiment suggests the possibility of being able to communicate to those who are stone deaf the feeling, or, at all events, the rhythm of music. It is not music, of course, but, if you like to call it so, it is music *on one plane and without colour.* There is no appreciation of pitch or colour or of quality, and there is no effort at analysis, an effort which, I believe, has a great deal to do with the pleasurable sensation we derive from music. In this experiment you have the rhythm which enters largely into musical feeling. Recently, through the kindness of Dr. J. Kerr Love, I had the opportunity of experimenting with four patients from the Deaf and Dumb Institution, one of whom had her hearing till she was eleven years of age, and then she became stone deaf. This girl had undoubtedly a recollection of music, although she does not now hear any sound. She wrote me a little letter, in which she declared that *what she felt was music*, and that it awakened in her mind a conscious something that recalled what music was The others had no conception of music, but they were able to appreciate the rhythm, and it was interesting to notice how they all, without exception, caught up the rhythm, and bobbed their heads up and down, keeping time with the electrical thrills in their finger-tips.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—The establishment of a University Lectureship in Experimental Psychology was opposed in the Senate, but it has now been carried by a very large majority.

Thirty-three men and three women have obtained a first-class in the Natural Sciences Tripos, Part I. In Part II. the first-class includes eleven names.

Prof. Allbutt, F.R.S., has been appointed to represent the University at the International Medical Congress to be held at Moscow in August.

The Harkness Scholarship in Geology and Palæontology has been awarded to Mr. R. H. Kitson, of Trinity College.

The Observatory Syndicate report that, Mr. Newall's term of office as Observer having expired, he has generously undertaken to continue to give his services without stipend for another term of five years. They think, however, that the provision of a stipend for the Newall Observer is an urgent claim on the funds of the University. In its present impoverished state the University is much indebted to Mr. Newall for his devoted and efficient aid in the department of physical astronomy. The portion of the catalogue of the *Astronomische Gesellschaft* allotted to Cambridge has now been published, after twenty-five years' work carried out for the most part by Mr. A. Graham. It refers to the zone 25° to 30°, and contains the places of 14,464 stars, obtained from about 47,570 observations. A new photographic telescope is being made for the observatory by Sir Howard Grubb, and the building for its accommodation will be taken in hand this summer.

The Special Board for Physics and Chemistry have, as was anticipated, withdrawn their proposals that the laboratory note-books of candidates for the first part of the National Sciences Tripos should be submitted to the examiners. They adhere to the proposal, in a modified form, as regards the second part of the examination. It is, however, provided that no marks shall be assigned for the note-books, the inspection of which is intended simply to give some guidance to the examiners in estimating the value of the practical part of the examination.

The first dissertations offered by advanced (post-graduate) students as candidates for the B.A. degree have been submitted and approved. Mr. J. S. E. Townsend and Mr. E. Rutherford have each offered memoirs on electrical subjects which have been honoured by publication in the *Phil. Trans.* of the Royal Society, and the Degree Committee record their opinion that the work submitted "is of distinction as a record of original research." These gentlemen have accordingly received the University Certificate of Research, and the degree of Bachelor of Arts, under the new regulations for graduates of other Universities.

The Hutchinson Studentship has been awarded to Mr. V. H. Blackman, of St. John's College, for botanical researches on Algæ. The Hockin Prize for Electricity has been awarded to Mr. W. A. D. Rudge, of the same college, a student in his first year.

THE University of Dublin has conferred the honorary degree of Doctor of Science upon Dr. Wilhelm His, Professor of Anatomy in Leipzig University, and Prof. Ramsay.

THE will of the late Mr. J. H. R. Molson has been admitted to probate at Montreal. It assigns 100,000 dollars to McGill University, 30,000 dollars to the Frazer Institute, and 10,000 dollars to Bishop's College School at Lennoxville.

ON Thursday last a farewell address was presented to Prof. Sollas, F.R.S., by past and present students of geology in Trinity College, Dublin. Prof. Sollas is leaving Dublin for Oxford, where he succeeds the late Prof. Green as professor of geology.

ENDOWMENTS recently received by Rutgers College increase the fund nearly 50,000 dollars, and include 5000 dollars from the Vice-President of the United States; 10,000 from Mrs. Winants, of Brooklyn; 5000 each from Mr. Frederick Frelinghuysen, of Newark, and Mr. Samuel Sloan and Mr. Richard Schlett, of New York, with the promise of 10,000 more from the latter; and 3234 from the Alumni Association.

IN order to obtain an accurate conception of the growth of Harvard University, Prof. C. S. Minot has compiled a table showing the gifts of money to Harvard College from 1868 to 1896, and he makes it the subject of a contribution to the Harvard *Graduate's Magazine* for June. It appears from this article that Harvard University has received annually during the past twenty-eight years in round numbers 330,000 dollars. The educational efficiency of the University has increased even faster than its endowment. It is held that seven scientific departments, in which the Medical, Dental, and Veterinary Schools have a common interest, need immediate endowment. The departments are: (1) anatomy (human and comparative); (2) physiology; (3) histology and embryology; (4) pathology; (5) bacteriology; (6) pharmacology; (7) hygiene. Each of the seven departments needs to be organised on the minimum basis of 300,000 dollars, making in all an endowment of 2,100,000 dollars. If the gifts continue as heretofore, six years would suffice to furnish the required amount. It is suggested that the development of the seven departments mentioned would be facilitated by the consolidation of the Medical, Dental, and Veterinary Schools under a single Faculty.

THE following are among recent appointments:—Mr. J. R. Campbell, of the Glasgow Technical College, to be lecturer in agriculture at the Harris Institute, Preston; Prof. W. T. Engelmann, of Utrecht, to succeed the late Prof. Du Bois Reymond in the chair of physiology in the University of Berlin; Dr. W. B. Pillsbury to be instructor in psychology in the University of Michigan; Dr. C. E. Seashore to be assistant in psychology in the University of Iowa; Mr. S. I. Franz to be assistant in psychology in Columbia University; Prof. William S. Franklin to be professor of physics and electrical engineering at Lehigh University; Dr. John Marshall to be professor of chemistry in the medical department of the University of Pennsylvania; Miss Bertha Stoneman to be professor of botany in the Huguenot College for Women in Cape Colony; Prof. J. L. Prevost to be professor of physiology in the University of Geneva; Dr. P. Francotte to be professor of embryology and Dr. P. Stroobant professor of astronomy in the University of Brussels; Dr. J. J. Zumstein to be professor of anatomy in the University of Marburg; Dr. Fuchs, privat-docent in palæontology and director of the geological section of the Natural History Museum at Munich, to be assistant professor; Dr. H. Baum, prosector and privat-docent in osteology at the Dresden Technical High School, to be professor; Dr. W. Ule, privat-docent in geography at Halle, to be professor; Dr. J. J. Ptaschicky to be professor of geometry at St. Petersburg; Dr. A. O. Kihlman to be assistant professor of botany at Helsingfors; Dr. Heim to be assistant professor of hygiene at Erlangen; Dr. Alex. Bittner to be chief geologist of the K. K. geologischen Reichsanstalt at Vienna; also, at the same institution, G. Geyer to be geologist, G. v. Bukowski and August Rosiwal to be adjunkten, and Dr. J. Dreger, F. Eichleiter, Dr. F. v. Kerner, and Dr. J. J. Jahn to be assistants.

SOCIETIES AND ACADEMIES.

LONDON.

Physical Society, June 25.—Mr. Shelford Bidwell, President, in the chair.—A paper by Mr. Sutherland, on a new theory of the earth's magnetism, was taken as read.—Dr. Kuenen described some experiments on critical phenomena, made in continuation of a research on the condensation and critical phenomena of mixtures of ethane and nitrous oxide, the results of which were published last year. The author now investigates mixtures of ethane and acetylene, and mixtures of ethane and carbonic acid, and finds for them similar properties to those of the mixtures of ethane and nitrous oxide. The first part of the paper refers to the preparation of ethane, and the effect of impurities on its vapour-pressure, and critical constants.